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(54) **COATED INSERTS FOR ROUGH MILLING**

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(58) **Field of Search** 409/64, 84; 427/249.17, 427/249.19, 255.22, 255.23, 255.28, 255.36

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,674,564	A	*	10/1997	Ljungberg et al.
5,861,210	A	*	1/1999	Lenander et al.
5,863,640	A	*	1/1999	Ljungberg et al.
5,912,051	A	*	6/1999	Olsson et al.
6,062,776	A	*	5/2000	Sandman et al.
6,177,178	B1	*	1/2001	Östlund et al.
6,406,224	B1	*	6/2002	Östlund et al.

FOREIGN PATENT DOCUMENTS

WO	01/16388	*	3/2001

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(57) **ABSTRACT**

Coated milling insert has a WC—Co cemented carbide with a low content of cubic carbides and a highly W-alloyed binder phase and a coating including an inner layer of TiC_xN_y with columnar grains followed by a layer of κ-Al_2O_3 and a top layer of TiN. The coated milling insert is particularly useful for milling of grey cast iron with or without cast skin under wet conditions at low and moderate cutting speeds and milling of nodular cast iron and compacted graphite iron with or without cast skin under wet conditions at moderate cutting speeds.

7 Claims, No Drawings

COATED INSERTS FOR ROUGH MILLING

This application is a divisional of application Ser. No. 09/984,145, filed on Oct. 29, 2001,now U.S. Pat. No. 6,638,609.

This application claims priority under 35 U.S.C. §§119 and/or 365 to Application No. 004079-0 filed in Sweden on Nov. 8, 2001, the entire content of which is hereby incorporated by reference.

BACKGROUND

1. Field of the Invention

The present invention relates to coated cemented carbide cutting tool inserts, particularly useful for milling of grey cast under wet conditions, preferably at low and moderate cutting speeds but also for milling of nodular cast iron and compacted graphite iron under wet conditions at moderate cutting speeds.

2. Background of the Invention

It is well known that for cemented carbide cutting tool inserts used in the machining of cast irons, the cutting edge is worn by different wear mechanisms such as chemical and abrasive wear but the cutting edge is generally also subjected to crack formation due to the intermittent cutting load, resulting in so called chippings and edge fractures caused by different types of cracks in the inserts.

Different types of crack patterns may appear during machining of cast irons. One important type is the so called comb cracks, which are formed perpendicularly to the cutting edge. The formation of comb cracks is strongly influenced by the cooling conditions during cutting. In particular, the use of fluid coolant increases the tendency to form comb cracks, often also called thermal cracks. The use of fluid coolant leads to large temperature gradients and thermal tensile stresses in the insert surface, increasing the tendency for formation of surface cracks, in particular in the case of coated cutting tool inserts where the hard but brittle ceramic surface coating is prone to crack under conditions involving unfavourable thermal tensile stresses. Cracks in the coating increases the risk for chipping and edge fractures and for flaking of the coating.

Characteristic for cast irons is the so called surface skin, the surface zone of the cast component often contains a structure which deviates considerably from the bulk structure and also contains hard inclusion and sand from the mould. In this case, a coated cemented carbide insert must be used including a substrate with the proper toughness of the cemented carbide grade and on the surface a wear resistant refractory coating.

Furthermore, different cutting conditions such as cutting speed, depth of cut, cutting feed rate and also external factors such as vibrations of the work piece and the above mentioned surface zone in iron casting, etc. , require a plurality of different properties of the cutting edge.

Commercial cemented carbide tool inserts for milling of cast irons under wet conditions are usually optimised with respect to one or two of the wear types observed.

U.S. Pat. No. 5,912,051 discloses a coated cutting insert particularly useful for dry milling of grey cast iron.

U.S. Pat. No. 5,863,640 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel.

In U.S. Pat. No. 6,062,776 is disclosed a coated cemented carbide cutting tool particularly designed for the wet and dry milling of workpieces of low and medium alloyed steels or

stainless steels, with or without abrasive surface zones, in machining operations requiring a high degree of toughness of the carbide cutting edge. The external cutting conditions are characterised by complex shapes of the workpiece, vibrations, chip hammering, recutting of the chips etc.

In U.S. Pat. No. 6,177,178 is disclosed a coated cemented carbide cutting tool particularly designed for the wet and dry milling of low and medium alloyed steels.

WO 01/16388 discloses a coated insert particularly useful for milling in low and medium alloyed steels with or without abrasive surface zones during dry or wet conditions at high cutting speed, and milling hardened steels at high cutting speed.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

It has now surprisingly been found that by combining many different features cutting tool inserts, preferably for milling, can be obtained with excellent cutting performance when milling grey cast iron using fluid coolant at low and moderate cutting speeds as well as in milling of nodular and compacted graphite iron using fluid coolant at moderate cutting speeds, in iron castings with or without cast skin.

The cutting tool inserts according to the invention show improved properties with respect to the different wear types prevailing at these cutting conditions as earlier mentioned.

The cutting tool inserts according to the invention consist of: a cemented carbide body with a relatively high W-alloyed binder phase and with a well balanced chemical composition and grain size of the WC, a columnar TiC_xN_y-layer, a κ-Al_2O_3-layer, a TiN-layer and optionally followed by smoothening the cutting edges by brushing the edges.

According to the present invention coated cutting tool inserts are provided consisting of a cemented carbide body with a composition of 7.3–7.9 wt. % Co, preferably 7.6 wt. % Co, 1.0–1.8 wt. % cubic carbides, preferably 1.4–1.7 wt. % cubic carbides of the metals Ta and Nb and balance WC. The average grain size of the WC is in the range of about 1.5–2.5 μm, preferably about 1.8 μm.

The cobalt binder phase is rather highly alloyed with W. The content of W in the binder phase can be expressed as the CW-ratio:

$$\text{CW-ratio}=Ms/(\text{wt \% Co} \times 0.0161)$$

where Ms is the saturation magnetization of the cemented carbide body in kA/m and wt. % Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A high CW-value corresponds to a low W-content in the binder phase.

It has now been found according to the present invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.86–0.94. The cemented carbide may contain small amounts, <3 vol. %, of η-phase (M_6C), without any detrimental effect.

The coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, y>x and z<0.2, preferably y>0.8 and z=0, with equiaxed grains with size <0.5 μm and a total thickness <1.5 μm preferably >0.1 μm.
- a layer of TiC_xN_y with x+y=1, x>0.3 and y>0.3, preferably x≧0.5, with a thickness of 1–4 μm, preferably 2–2.7 μm, with columnar grains and with an average diameter of <5 μm, preferably 0.1–2 μm.
- a layer of a smooth, fine-grained (grain size about 0.5–2 μm) Al_2O_3 consisting essentially of the κ-phase.

However, the layer may contain small amounts (<5 vol. %) of other phases such as η- or the α-phase as determined by XRD-measurement. The Al_2O_3-layer has a thickness of 1–2.5 μm, preferably 1.2–1.7 μm.

a further 0.5–1.0 μm thick layer of TiN. This outermost layer of TiN has a surface roughness Rmax≦0.4 μm over a length of 10 μm. The TiN-layer is preferably removed along the cutting edge and the underlying alumina layer may be partly or completely removed along the cutting edge.

The present invention also relates to a method of making coated cutting tool inserts consisting of a cemented carbide body with a composition of 7.3–7.9 wt. % Co, preferably 7.6 wt. % Co, 1.0–1.8 wt. % cubic carbides, preferably 1.4–1.7 wt. % cubic carbides of the metals Ta and Nb and balance WC. The average grain size of the WC is in the range of about 1.5–2.5 μm, preferably about 1.8 μm. Onto the cemented carbide body is deposited

a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, y>x and z<0.2, preferably y>0.8 and z=0, with equiaxed grains with size <0.5 μm and a total thickness <1.5 μm preferably >0.1 μm using known CVD-methods.

a layer of TiC_xN_y with x+y=1, x>0.3 and y>0.3, preferably x≧0.5, with a thickness of 1–4 μm, preferably 2–2.7 μm, with columnar grains and with an average diameter of <5 μm, preferably 0.1–2 μm using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700–900° C.). The exact conditions, however, depend to a certain extent on the design of the equipment used.

a smooth Al_2O_3-layer essentially consisting of κ-Al_2O_3 is deposited under conditions disclosed in e.g. U.S. Pat. No. 5,674,564. The Al_2O_3 layer has a thickness of 1–2.5 μm, preferably 1.2–1.7 μm.

a 0.5–1.0 μm thick layer of TiN with a surface roughness Rmax≦0.4 μm over a length of 10 μm.

The smooth coating surface is obtained by a gentle wet-blasting the coating surface with fine grained (400–150 mesh) alumina powder or by brushing the edges with brushes based on e.g. SiC as disclosed e.g. in U.S. Pat. No. 5,861,210. The TiN-layer is preferably removed along the cutting edge and the underlying alumina layer may be partly or completely removed along the cutting edge.

The invention also relates to the use of cutting tool inserts according to above for wet milling using fluid coolant of cast irons such as grey cast iron, compacted graphite iron and nodular iron particularly grey cast iron at a cutting speed of 70–180 m/min and a feed of 0.1–0.4 μm/tooth depending on cutting speed and insert geometry.

EXAMPLE 1

A. Cemented carbide milling inserts in accordance with the invention with the composition 7.6 wt. % Co, 1.25 wt. % TaC, 0.30 wt. % NbC and balance WC with average grain size of 1.8 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.87 were coated with a 0.5 μm equiaxed $TiC_{0.05}N_{0.95}$-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 2.6 μm thick $TiC_{0.54}N_{0.46}$-layer, with columnar grains by using MTCVD-technique (temperature 850–885° C. and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.3 μm thick layer of Al_2O_3 was deposited using a temperature 970° C. and a concentration of H_2S dopant of 0.4% as disclosed in U.S. Pat. No. 5,674,564. A thin (0.5 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100% κ-phase.

The coated inserts were brushed using a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light optical microscope revealed that the outermost, thin TiN-layer and some of the Al_2O_3-layer had been brushed away along the very cutting edge, leaving there a smooth Al_2O_3-surface. Coating thickness measurements on cross sectioned, brushed inserts showed that the outermost TiN-layer and roughly half the Al_2O_3-layer had been removed along the edge line.

B. Commercial cemented carbide milling inserts with the composition 9 wt. % Co, 1.23 wt. % TaC, 0.30 wt. % NbC and balance WC with a WC grain size in average of 1.7 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.92 were coated with an innermost 0.5 μm equiaxed TiN-layer followed by a 5.5 μm thick Ti(C,N)-layer, with columnar grains by using MTCVD-technique and outermost a 4 μm thick layer of Al_2O_3. XRD-measurement showed that the Al_2O_3-layer consisted of 100% α-phase.

C. Cemented carbide milling inserts with the composition 6 wt. % Co and balance WC with average grain size 1.8 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.90 were coated with a 2 μm thick TiC-layer using known CVD-technique. In subsequent steps during the same coating cycle, a 1 μm thick layer of Al_2O_3 was deposited.

Inserts from A, B and C were tested in face milling of grey cast iron cylinder heads.

Operation:	Face milling - roughing
Work-piece:	Cylinder head
Material:	Pearlitic grey cast iron, alloyed,
Cutting speed:	116 m/min
Feed rate/tooth:	0.32 μm/rev.
Depth of cut:	2 μm
Insert-style:	TNEF 1204AN-CA
Note:	Wet, single tooth milling
Results:	Tool-life, number of passes per edge
Grade A: (invention)	99
Grade B: (prior art)	60
Grade C: (prior art)	49

Tool-life criterion was chippings and fractures of the edges.

EXAMPLE 2

D. Cemented carbide milling inserts in accordance with the invention with the composition 7.6 wt. % Co, 1.25 wt. % TaC, 0.30 wt. % NbC and balance WC with an average grain size of 1.75 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.88 were coated with a 0.5 μm equiaxed $TiC_{0.05}N_{0.095}$-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 2.0 μm thick $TiC_{0.54}N_{46}$-layer, with columnar grains by using MTCVD-technique (temperature 850–885° C. and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.4 μm thick layer of Al_2O_3 was deposited using a temperature 970° C. and a concentration of H_2S dopant of 0.4% as disclosed in U.S. Pat. No. 5,674,564. A thin (0.5 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100% κ-phase.

The coated inserts were brushed using a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light optical microscope showed that the outermost, thin TiN-layer and some of the Al_2O_3-layer had been brushed away along the very cutting edge, leaving there a smooth Al_2O_3-surface. Coating thickness measurements on cross sectioned, brushed inserts showed that the outermost TiN-layer and roughly half the Al_2O_3-layer had been removed along the edge line.

Inserts from D and C were tested in face milling of grey cast iron cylinder heads.

Operation:	Face milling - roughing
Work-piece:	Cylinder head
Material:	Pearlitic grey cast iron, alloyed,
Cutting speed:	116 m/min
Feed rate/tooth:	0.32 μm/rev.
Depth of cut:	1.5–2 μm
Insert-style:	TNEF 1204AN-CA
Note:	Wet, 13 teeth, unstable tendencies
Results:	Tool-life, number of component per edge set
Grade D: (invention)	685
Grade C: (prior art)	475

Tool-life criterion was edge break-out on the work piece due to chipping and high flank wear of the edges.

EXAMPLE 3

E. Cemented carbide milling inserts in accordance with the invention, identical to the inserts described in D (Example 2), except for that the coating not was brushed.

Inserts from D and E were tested in face milling of grey cast iron cylinder heads.

Operation:	Face milling - roughing
Work-piece:	Cylinder head
Material:	Pearlitic grey cast iron, alloyed,
Cutting speed:	116 m/min
Feed rate/tooth:	0.32 μm/rev.
Depth of cut:	1.5–2 μm
Insert-style:	TNEF 1204AN-CA
Note:	Wet, 13 teeth, unstable tendencies
Results:	Tool-life, number of component per edge set
Grade D: (invention)	685
Grade E: (outside invention)	570

Tool-life criterion was edge break-out on the work piece due to chipping and high flank wear of the edges.

EXAMPLE 4

F. Cemented carbide milling inserts in accordance with the invention with the composition 7.6 wt. % Co, 1.25 wt. % TaC, 0.30 wt. % NbC and balance WC with a grain size in average of 1.79 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5 μm equiaxed $TiC_{0.05}N_{0.95}$-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 2.7 μm thick $TiC_{0.54}N_{0.46}$-layer, with columnar grains by using MTCVD-technique (temperature 850–885° C. and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.2 μm thick layer of Al_2O_3 was deposited using a temperature 970° C. and a concentration of H_2S dopant of 0.4% as disclosed in U.S. Pat. No. 5,674,564. A thin (0.8 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100% κ-phase.

The coated inserts were brushed using a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light optical microscope showed that the outermost, thin TiN-layer and some of the Al_2O_3-layer had been brushed away along the very cutting edge, leaving there a smooth Al_2O_3-surface. Coating thickness measurements on cross sectioned, brushed inserts showed that the outermost TiN-layer and roughly half the Al_2O_3-layer had been removed along the edge line.

G. Commercial cemented carbide milling inserts with the composition of 8 wt-% Co, 0.1 wt-% TiC, 1.7 wt-% TaC, 0.1 wt-% NbC, and balance WC and CW-ratio of 0.86. The WC-grain size was 1.74 μm. The inserts were coated with a 0.5 μm TiN-layer followed by a 1.5 μm thick TiC-layer and finally followed by a 0.5 μm TiN-layer.

H. Commercial cemented carbide cutting inserts with the composition of 8 wt. % Co, 0.1 wt. % TiC, 1.8 wt. % TaC, 0.1 wt. % NbC and balance WC, CW-ratio of 0.86 and WC-grain size 1.71 μm were coated with a 5 μm TiAlN-layer deposited by PVD-technique.

Inserts from F, G and H were tested in face milling of an alloyed pearlitic grey cast iron cylinder head.

Operation:	Face milling - roughing
Work-piece:	Cylinder head
Material:	Pearlitic grey cast iron, alloyed.
Cutting speed:	116 m/min
Feed rate/tooth:	0.32 μm/rev
Depth of cut:	2 μm
Insert-style:	TNEF 1204AN
Note:	Wet, single tooth milling
Results:	Tool-life, number of passes per edge
Grade F: (invention)	78
Grade G: (prior art)	60
Grade H: (prior art)	58

Tool-life criterion was chippings and edge fractures of the edges.

EXAMPLE 5

I. Cemented carbide milling inserts in accordance with the invention with the composition 7.6 wt. % Co, 1.25 wt. % TaC, 0.30 wt. % NbC and balance WC with a grain size in average of 1.75 μm, with a binder phase alloyed with W corresponding to a CW-ratio of 0.90 were coated with a 0.5 μm equiaxed $TiC_{0.05}N_{0.95}$-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 2.7 μm thick $TiC_{0.54}N_{0.46}$-layer, with columnar grains by using MTCVD-technique (temperature 850–885° C. and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.7 μm thick layer of Al_2O_3 was deposited using a temperature 970° C. and a concentration of H_2S dopant of 0.4% as disclosed in U.S. Pat. No. 5,674,564. A thin (0.7 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100% κ-phase.

The coated inserts were brushed using a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light optical microscope showed that the outermost, thin TiN-layer and some of the Al_2O_3-layer had been brushed away along the very cutting edge, leaving there a smooth A1203-surface. Coating thickness measurements on cross sectioned, brushed inserts showed that the outermost TiN-layer and roughly half the Al_2O_3-layer had been removed along the edge line.

Inserts from I and G were tested in face milling of pearlitic grey cast iron engine blocks.

Operation:	Face milling - roughing
Work-piece:	Engine block
Material:	Pearlitic grey cast iron, un-alloyed
Cutting speed:	106 m/min
Feed rate/tooth:	0.20 μm/rev
Depth of cut:	3 μm
Insert-style:	TNEF 1204AN
Note:	Wet milling, 56 teeth per set
Results:	Tool-life, number of components per set
Grade I: (invention)	975
Grade G: (prior art)	700

Tool-life criterion was edge break-out on the work piece due to chipping and high flank wear of the edges.

EXAMPLE 6

Inserts from I and B were tested in face milling of pearlitic nodular cast iron gearbox housing.

Operation:	Face milling - roughing
Work-piece:	Gear box housing.
Material:	Pearlitic nodular cast iron, alloyed
Cutting speed:	137 m/min
Feed rate/tooth:	0.15 μm/rev.
Depth of cut:	5 μm
Insert-style:	TNEF 1204AN-CA
Note:	Wet milling, 20 teeth, unstable tendencies
Results:	Tool-life, minutes of tool life per edge set
Grade I: (invention)	105
Grade B: (prior art)	60

Tool-life criterion was crack formation and chippings of the edges.

EXAMPLE 7

Inserts from I and C were tested in face milling of nodular cast iron engine block component

Operation:	Face milling - roughing
Work-piece:	Engine block, bearing part
Material:	Nodular cast iron
Cutting speed:	93 m/min
Feed rate/tooth:	0.25 μm/rev.
Insert-style:	TNEF 1204AN-CA
Note:	Wet milling, 26 teeth
Results:	Tool-life, number of components per edge set
Grade I: (invention)	38000
Grade C: (prior art)	20000

Tool-life criterion was burr and spalling on the work piece.

What is claimed is:

1. A method of making a milling insert comprising a cemented carbide body and a coating wherein the WC-Co-based cemented carbide body comprises WC, 7.3–7.9 wt. % Co and 1.0–1.8 wt. % cubic carbides of Ta and Nb and a highly W-alloyed binder phase with a CW-ratio of 0.86–0.94, the method comprising the steps of:

depositing by a CVD-method a first, innermost layer of $TiC_xN_yO_z$ with x+y+z=1, y>x and z<0.2 having an equiaxed grain structure with a size <0.5 μm and a total thickness of 0.1–1.5 μm;

depositing by a MTCVD-technique a layer of TiC_xN_y with x+y=1, x>0.3 and y>0.3 with a thickness of 1–4 μm having a columnar grain structure with an average diameter of <5 μm, wherein the MTCVD-technique uses acetonitrile as a source of carbon and nitrogen for forming a layer in a temperature range of 700–900° C.;

depositing a layer of a smooth κ-Al_2O_3 with a thickness of 1–2.5 μm; and

depositing an outer layer of TiN with a thickness of 0.5–1.0 μm.

2. The method according to the claim **1**, wherein the cemented carbide body contains 1.4–1.7 wt. % carbides of Ta and Nb.

3. The method according to claim **1**, further comprising the step of removing the outer layer of TiN along a cutting edge.

4. The method of making a milling insert of claim **1**, wherein the first, innermost layer of $TiC_xN_yO_z$ has y>0.8 and z=0.

5. The method of making a milling insert of claim **1**, wherein the layer of TiC_xN_y has x≧0.5.

6. A method of wet milling comprising the steps of:

providing a cutting tool insert comprising a cemented carbide body comprising WC, 7.3–7.9 wt. % Co, 1.0–1.8 wt. % cubic carbides of Ta and Nb, and a highly W-alloyed binder phase with a CW-ratio of 0.86–0.94, a coating comprising a first, innermost layer of $TiC_xN_yO_z$ with x+y+z=1, y>x and z<0.2 having an equiaxed grain structure with a size <0.5 μm and a total thickness of 0.1–1.5 μm, a layer of TiC_xN_y with x+y=1, x>0.3 and y>0.3 with a thickness of 1–4 μm having a columnar grain structure with an average diameter of <5 μm, a layer of a smooth, fine-grained, 0.5–2 μm κ-Al_2O_3 with a thickness of 1–2.5 μm, and an outer layer of TiN with a thickness of 0.5–1.0 μm;

operating the cutting tool insert at a speed of 70–180 m/min; and

feeding at a rate of 0.1–0.4 μm/tooth, wherein the wet milling is wet milling a cast iron, a compacted graphite iron or a nodular iron.

7. The method of claim **6**, wherein the cast iron is a grey cast iron.

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